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Flexure and Shear Study of Deep Beams using Metakaolin Added Polypropylene Fibre Reinforced Concrete

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***Abstract*— *Structural elements like walls of bunkers, load bearing walls in buildings, pile caps, plate elements in folded plates behave as deep beams. Beams whose span (L) to depth (D) ratio is reasonably small can be said as a deep beam. Beams with large depth, supported by individual columns, often used as transfer girders in tall buildings, long span structures etc are commonly referred to as deep beams. Deep beams are used for architectural buildings where the span is very large without any intermediate columns such as marriage halls, assembly halls, auditoriums, theatres etc. According to IS456-2000, a beam is said to be as a deep beam when the ratio of effective span to overall depth (L/D) is less than 2.0 for simply supported members and 2.5 for continuous members. The design of such structural elements requires innovative procedures to serve the functionality coupled with durability. In deep beams, the bending stress distribution across any transverse section deviates appreciably from the straight line distribution assumed as in the simple beam theory. So, assumption of "Plane section before bending remains plane after bending" does not become valid and the neutral axis does not lies at the mid depth. In deep beams, the ultimate failure due to shear is generally brittle in nature, in disparity to the ductile behavior and progressive failure with large number of cracks as observed in normal beams.*

In this paper, flexural strength of M20 and M30 graded concrete deep beams with the addition of a combination of 0%,10%,20% metakaolin as a partial replacement for cement and 0%,2.5%,5% polypropylene fibre is found out and mode of failure is observed for each case. Mix designs for M20 and M30 graded concrete are carried out in worksheets and the proportions of cement, sand, coarse aggregate are calculated based on the tests conducted on cement and aggregates. Cubes are casted and 7 days compressive strengths for those cubes are tested using compressive testing machine and the mix proportions are used.

Keywords*— *Metakaolin, Polypropylene Fibre, Deep beam.

I. INTRODUCTION

1.1 DIFFERENCES BETWEEN SIMPLE BEAM AND DEEP BEAM

- Deep beams behave as two dimensional action whereas the simple beam behaves as one dimensional action.
- Plane section remains plane which is applicable in simple beams is not applicable for deep beams where the strain distribution is not linear.
- Shear deformation cannot be neglected in deep beams as in the case of ordinary beams. In deep beams, even at the elastic stage, stress distribution is not linear and in the ultimate limit state, the shape of the concrete compressive stress block is no longer parabolic.

1.2 IMAGES FOR SOME EXAMPLES OF DEEP BEAMS

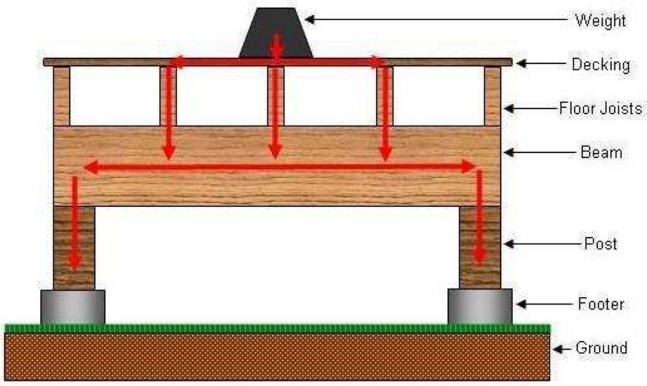

Fig.1.1: Transfer girder

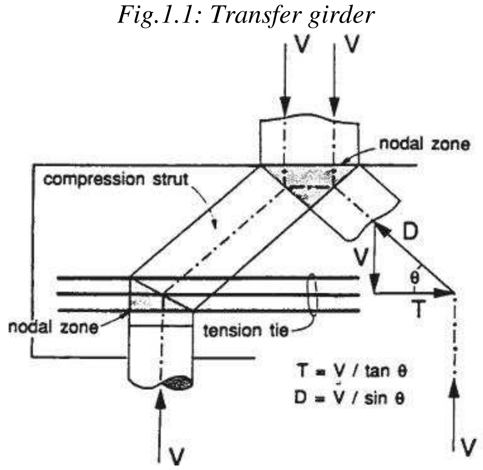

Fig.1.2: Pile cap as a Deep beam- Strut and Tie Model

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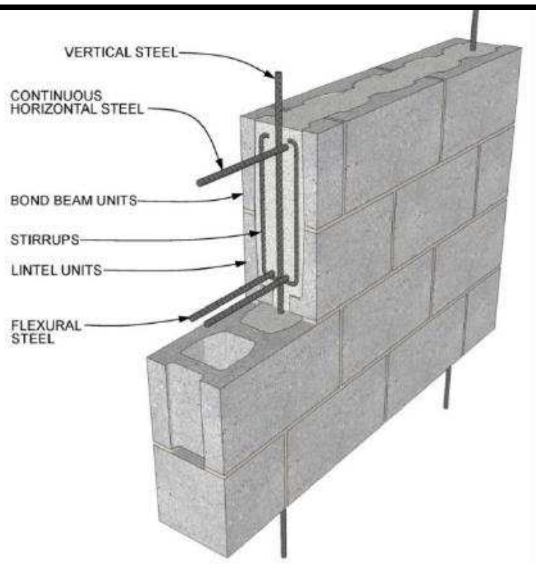
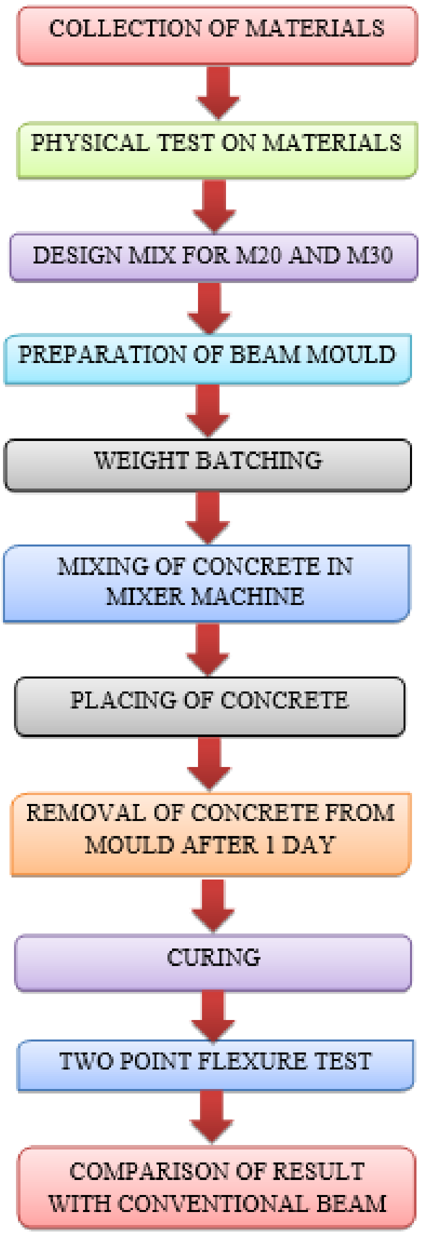


Fig.1.3: Walls of a Bunker as a deep beam

II. METHODOLOGY



III. EXPERIMENTAL WORK

3.1 MIX DESIGN FOR DEEP BEAMS

Mix design ratio for M20 grade concrete = 1:2.64:3.78

Mix design ratio for M30 grade concrete = 1:2.24:3.33

3.2 PROPERTIES OF POLYPROPYLENE FIBER

Appearance	: polypropylene fiber
Specific gravity	: 0.91 g/cm2
Alkali content	: Nil
Sulphate content	: Nil
Air entrainment	: air content of concrete will not be significantly increased
Chlorine content	: Nil
Constituents	: Nil
Fiber thickness	: 6 denier
Young's modulus	: 5500-7000MPA
Tensile strength	: 360MPA
Fibre length	: 6mm
Aggregate max size	: 32mm

Fig.3.1: Polypropylene fibre

Fig.3.2: Metakaolin

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Fig.3.3: Placing the cube in CTM machine to check for design mix.

Fig.3.4: During Compression test of a cube in CTM

3.3 TEST RESULTS-GENERAL

Specific gravity of fine aggregate : 2.72
Water absorption of fine aggregate : 1.0%
Specific gravity of coarse aggregate : 2.68
Water absorption of coarse aggregate : 0.50
Specific gravity of cement : 3.15

3.4 TEST RESULTS FOR COMPRESSION TEST OF CUBES TO CHECK FOR THE DESIGN MIX FOR DEEP BEAMS

COMPRESSION TEST OF CUBE	LOAD	STRENGTH ACHIEVED	TARGETED STRENGTH
Compression test for M20 for 7 day	432kN	19.2	13
Compression test for M30 for 7 day	610kN	27.11	19.5

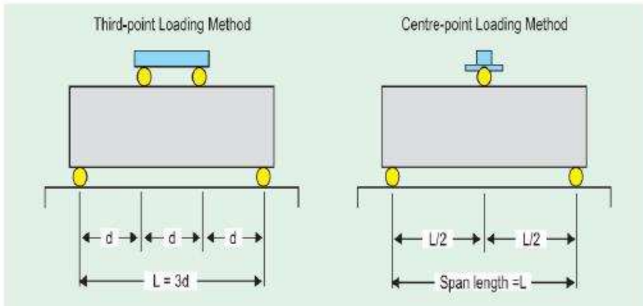

Fig.3.5: Flexural Test for Beams- Third Point Loading and Centre Point Loading

Fig.3.6: Deep Beam Mould

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Fig.3.7: Mixer Machine

Fig.3.8: Concrete Poured in Deep Beam Mould and leveled

Fig.3.9: Marking on Deep Beams for third Point Loading with a chalk

Fig.3.10: Flexure Test of a deep beam under third point loading in UTM of 400 kN capacity.

3.5 CALCULATION OF FLEXURAL STRENGTH

The mould for deep beam used in this project is 50cm length, 15cm breadth and 28cm depth. The cured beam is removed from the mould by screwing out the bolts and the beam is marked on the surrounding by four lines, two lines for resting on the support rollers and two in-between lines for the application of point loads in two points. Here the edge distance is 5 cm on both the edges and the remaining 40 cm is divided into three equal lengths such as 13.33 cm. The flexural strength of the specimen is expressed as the modulus of rupture f_b which if 'a ' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, is calculated to the nearest 0.05 MPa as follows:

$$f_b = PxL/bxd^2$$

When 'a ' is greater than 20.0 cm for 15.0 cm specimen.

$$f_b = 3Pxa/ bxd^2$$

When ' a ' is less than 20.0 cm but greater than 17.0 cm for 15.0 specimen,

where b = measured width in cm of the specimen.

d = measured depth in cm of the specimen.

P = Ultimate Load in kN.

L= Centre to Centre distance between supports.

3.6 FLEXURE TEST RESULTS FOR DEEP BEAM OF M20 GRADE PLAIN CONCRETE

S.NO	PPF %	METAKAOLIN %	TEST AT DAYS	FLEXURAL LOAD P(kN)	MIN LENGTH B/W CRACK AND EDGE AT NEUTRAL AXIS IN TENSION SIDE 'a' (cm)	FLEXURAL STRESS f_b (N/mm^2)	TYPE OF FAILURE
1	0	0	7	91	21	3.24	SB
2	0	10	7	85	17	3.82	CRACK
3	0	20	7	142	23	5	SB
4	2.5	10	7	73	23.4	2.57	CRACK
5	2.5	20	7	77	14	2.85	CRACK
6	5	10	7	60	15.5	2.46	CRACK
7	5	20	7	71	23	2.50	CRACK
8	0	0	21	115	22.5	4.05	SB
9	0	10	21	105	22.7	3.70	CRACK
10	0	20	21	110	21.8	3.87	SB
11	2.5	10	21	112	21.6	3.94	CRACK
12	2.5	20	21	96	22.5	3.38	CRACK
13	5	10	21	91	23	3.21	CRACK
14	5	20	21	84	18	3.99	CRACK

Note:- Where 'SB' denotes Sudden Breakage of deep beam into two parts

3.7 FLEXURE TEST RESULTS FOR DEEP BEAM OF M30 GRADE PLAIN CONCRETE

S.NO	PPF %	METAKAOLIN %	TEST AT DAYS	FLEXURAL LOAD P(kN)	MIN LEN B/W CRACK AND EDGE AT NEUTRAL AXIS IN TENSION SIDE 'a' (cm)	FLEXURAL STRESS f_b (N/mm^2)	TYPE OF FAILURE
1	0	0	7	94	21	3.31	SB
2	0	10	7	70	19.5	3.60	SB
3	0	20	7	76	23.7	2.67	CRACK
4	2.5	10	7	94	20.1	3.31	SB
5	2.5	20	7	75	24.7	2.64	CRACK
6	5	10	7	79	21.5	2.78	CRACK
7	5	20	7	67	20.2	2.36	CRACK
8	0	0	21	122	21	4.30	SB
9	0	10	21	102	22.5	3.62	SB
10	0	20	21	107	24.4	3.17	SB
11	2.5	10	21	106	24	3.73	CRACK
12	2.5	20	21	112	23.5	3.94	CRACK
13	5	10	21	57	19.9	3.68	CRACK
14	5	20	21	131	21.3	4.62	CRACK

Note:- Where 'SB' denotes Sudden Breakage of deep beam into two parts

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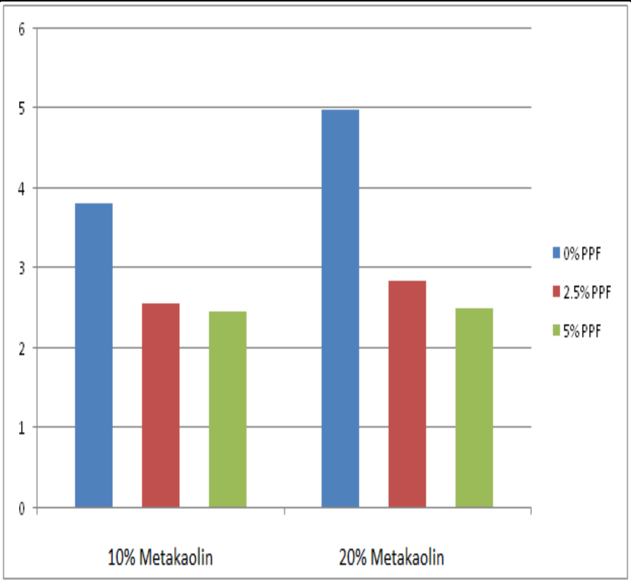

Fig.3.11: 7 Days Flexural Strength for M20

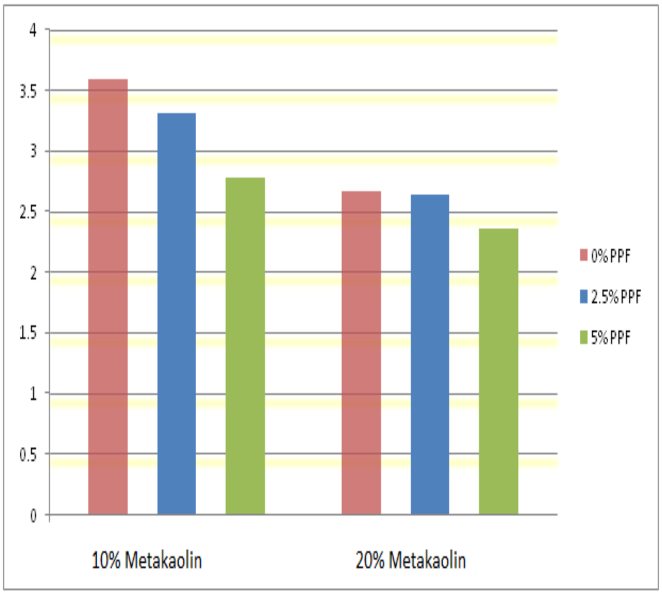

Fig.3.12: 7 Days Flexural Strength for M30

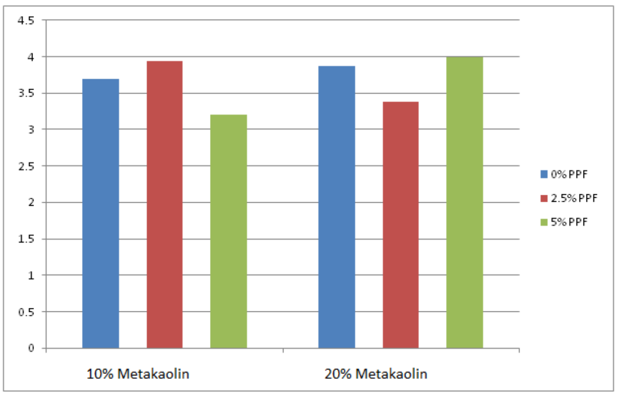

Fig.3.13:21 Days Flexural Strength for M20

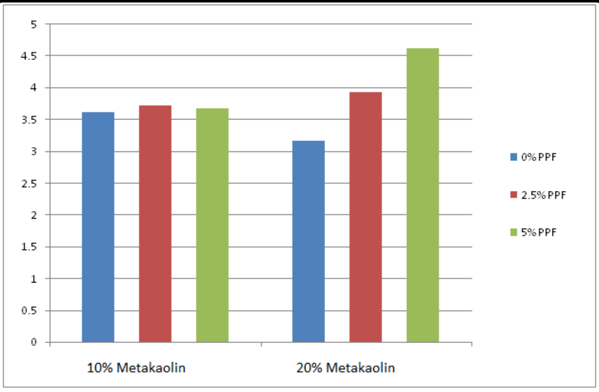

Fig.3.14: 21 Days Flexural Strength for M30

IV. SUMMARY AND CONCLUSION

On adding PPF, brittle failure is eliminated and only shear cracks are formed, thus ductile failure (failure with warning) takes place. Whereas on addition of PPF fiber, though flexural strength is less, the beam does not break and only cracks are formed and hence giving a full warning before failure.

By replacing cement with metakaolin, 7days strength of deep beams may be slightly below the targeted strength but 28 days predicted strength of deep beams might be more than the targeted strength as per 21 days flexural strength since metakaolin has to be cured for more days to achieve required strength.

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